Vaccine Distribution Between Neighbouring Countries During a Covid-like Pandemic

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Introduction

Under a limited supply of vaccines between three neighbouring countries during a Covid-like pandemic is it always beneficial for a country to hoard? Will the answer depend on the quantity of vaccines available as well as the key policy objective? We will model the transmission of a Covid-like disease in the UK and Ireland where we will consider the strategies of proportional distribution, equal distribution, and hoarding under the policy objectives of minimising deaths and minimising impact to the economy after two years.

Model & Assumptions

When a Susceptible (S) becomes Exposed (E), they go on to become Infectious (I). Upon isolation or hospitalisation they no longer infect others. A person will either recover (R) or die (D). Model adapted from [1].

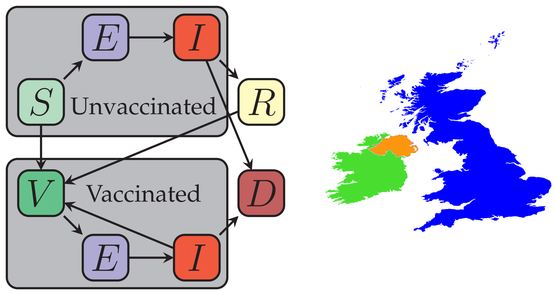

Figure 1: Simplified Illustration of Model

Outbreaks were simulated using a stochastic model where we assume travel between Britain (GB), Ireland (ROI), and Northern Ireland (NI) is aligned with pre-covid data when they are not in lockdown. Lockdowns are simulated by a reduced contact rate and reduced travel in and out of that country. They activate/deactivate based on the hospitalisations in a country.

Vaccine Strategy

We will consider three different limits on the monthly vaccine supply, 100,000, 500,000, and 5,000,000. Vaccines are first available on day 313 and new vaccines are available every 28 days following.

Average Number Vaccines Administered:

GB: 9,640,000 /Month **Population:** 64,765,000
ROI: 742,672 /Month **Population:** 4,904,000
NI: 272,048 /Month **Population:** 1,885,000

One Stochastic Realisation

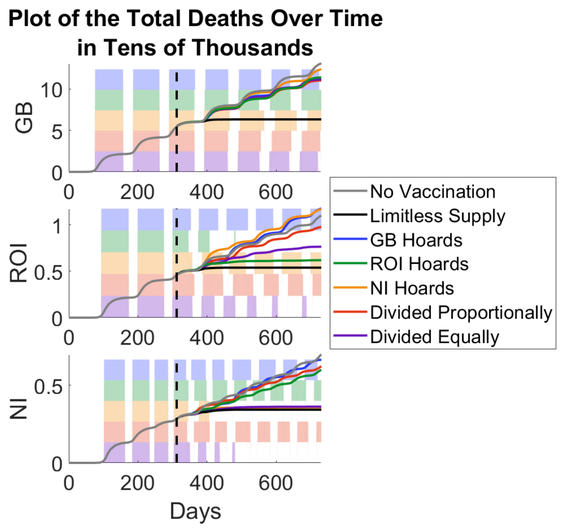

Figure 2: Representative Simulation

The background is shaded when the country is in lockdown under the strategy corresponding to the colour of the shading. This particular realisation considers 500,000 Vaccines/Month. We can see how the number and duration of lockdowns vary depending on the strategy in place.

Local Strategy

Minimising Deaths

Under a limited supply hoarding is advantageous if it is not greater than the number of vaccinations your country can achieve in a month. As shown in the table below a limited vaccine supply results in GB hoarding due to its population size. While NI and ROI will support an equal distribution for larger limited supplies to vaccinate its own people while also minimising foreign cases entering the country. When there are only 100,000 vaccines GB makes the unexpected decision to give all to ROI.

Vaccines	GB	ROI	NI
100,000	ROI	Hoard	Hoard
500,000	Hoard	Hoard	Hoard
5,000,000	Hoard	Equal	Equal

Table 1: Best Strategy for Each State to Minimise Deaths

Minimising Impact to Economy

We considered two aspects to the economy (E), income from number of tourists (T), [2], and loss of income due to days in lockdown (L), the equation for quantifying their impacts is shown below. We see that with small quantities of vaccine available the incentive is to vaccinate ROI. Eventually at 5,000,000 vaccines GB and NI opt to vaccinate proportional. However ROI will still hoard.

$$E = 976(\mathrm{T}) - 0.5(\mathrm{Population})(\mathrm{L})$$

Vaccines	GB	ROI	NI
100,000	ROI	Hoard	ROI
500,000	ROI	Hoard	ROI
5,000,000	Prop	Hoard	Prop

Table 2: Best Strategy for Each State to Minimise Impact to Economy

Global Strategy

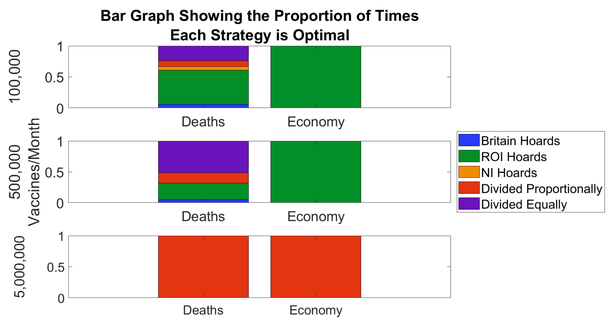

Figure 3: Proportion of Times Each Strategy is the Best under different vaccine supplies

Minimising Global Deaths

With only 100,000 vaccines, the best strategy is for ROI to hoard the vaccines. As we increase the supply the best strategy transitions to equal distribution and then to proportional distribution. By considering the global outbreak sharing of vaccine supply becomes preferable with a smaller supply than when only considering local strategy.

Minimising Impact to Global Economy

As with the local strategy, a vaccine supply of 500,000 or less leads to ROI hoarding the supply in order to minimise the impact. However, by increasing the supply to 5,000,000 we find that the best strategy is now a proportional distribution between the three nations.

References

[1] Sam Moore, Edward M Hill, Michael J Tildesley, Louise Dyson, and Matt J Keeling. Vaccination and non-pharmaceutical interventions for covid-19: a mathematical modelling study. *The Lancet Infectious Diseases*, 21(6):793–802, 2021.

[2] https://www.statista.com/. Average length of stay on holiday visits abroad by united kingdom (uk) residents from 2011 to 2019. 2021.

Conclusions

Local Deaths: We prioritise hoarding under a limited supply.

Local Economy: Sharing is encouraged either by proportional distribution or ROI hoards.

Global Deaths: Equal or proportional distributions are preferable.

Global Economy: ROI Hoarding is preferable or proportional for 5,000,000 vaccines